New Drought Indicators Based on GRACE Satellite Observations

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Drought costs the U.S. economy upwards of $8 billion per year. The U.S. Drought Monitor (USDM) is the nation's premier decision support tool for drought assessment, used by farmers, disaster aid officials, agricultural commodities interests, and even *USA Today*. Previously, the USDM authors had lacked information on groundwater storage conditions and had little objective information on soil moisture, two key indicators of drought. Through this project, those two information gaps are being filled, and the USDM authors are now testing the new drought indicators presented here as inputs to their maps.

Drought may be defined as a deficiency, relative to the long term average, of water stored on and in the land, including surface waters, soil moisture, and groundwater. The latter two variables are difficult to measure over large scales using conventional, ground-based techniques. Thanks to satellite observations from NASA's Gravity Recovery and Climate Experiment (GRACE) mission, such data are now becoming available. However, GRACE's spatial and temporal resolutions are low, there is a data latency of 2-3 months, and GRACE does not differentiate one form of land water storage from another. By synthesizing GRACE with other observations within a sophisticated numerical model of land surface water and energy processes, we are able to generate weekly data fields of wetness conditions in the soil and shallow aquifers, with the resolution and timeliness necessary for operational drought monitoring (Figure 1). Maps of these data fields are available from **http://www.drought.unl.edu/MonitoringTools.aspx**

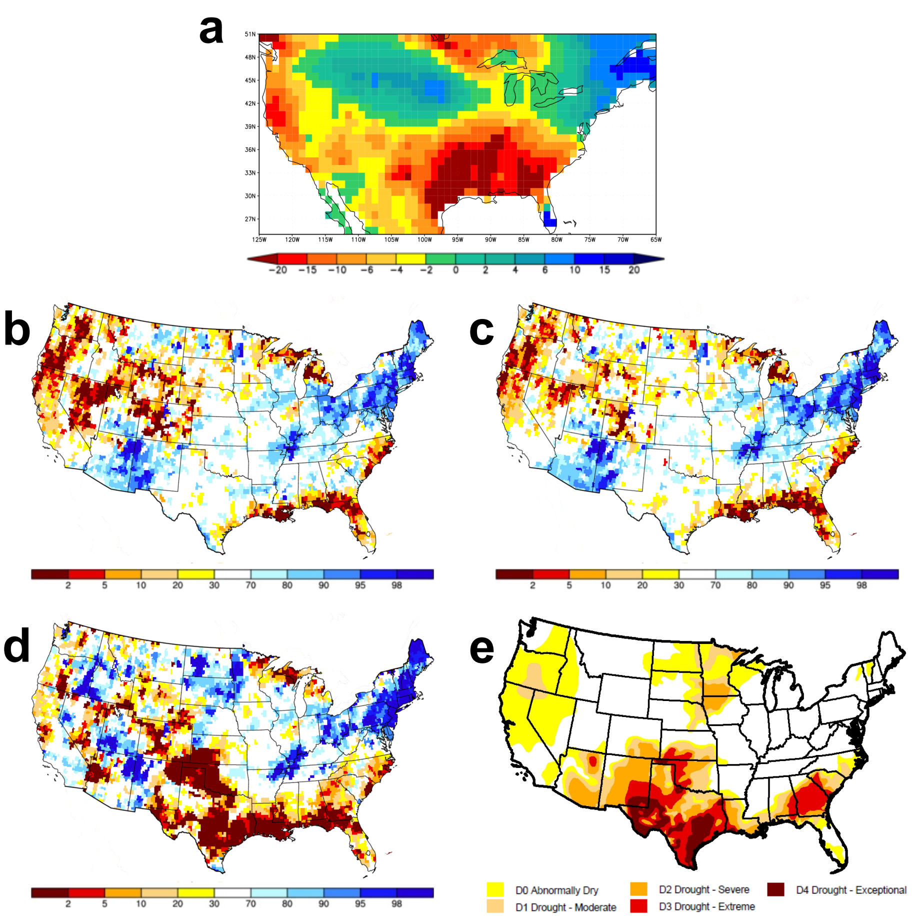

Figure 1: (a) GRACE terrestrial water storage anomalies (cm equivalent height of water) for November 2011; (b-d) surface soil moisture, root zone soil moisture, and groundwater drought indicators from GRACE data assimilation (wetness percentiles relative to the period 1948-present) for 26 December 2011; (e) U.S. Drought Monitor product for 27 December 2011.

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References:

1. Houborg, R., M. Rodell, B. Li, R. Reichle, and B. Zaitchik, Drought indicators based on model assimilated GRACE terrestrial water storage observations, Water Resources Research, in review, 2012.
2. Rodell, M., "Satellite gravimetry applied to drought monitoring", chapter in Remote Sensing of Drought: Innovative Monitoring Approaches, B. Wardlow, M. Anderson, and J. Verdin, Eds., CRC Press/Taylor and Francis, in press, 2012.

Data Sources: The new drought indicator products and U.S. Drought Monitor are available from http://www.drought.unl.edu/MonitoringTools.aspx . GRACE terrestrial water storage data were processed by Sean Swenson and are available from http://grace.jpl.nasa.gov .

Technical Description of Figure:

Figure 1: This figure compares (a) the GRACE satellite based map of anomalies (deviations from the long term mean at a given location) of terrestrial water storage (the sum of groundwater, soil water, surface water, snow, and ice, as an equivalent height of water in cm) for the month of November 2011 (the most recent available at the time of writing) with drought indicator maps for (b) surface soil moisture, (c) root zone soil moisture, and (d) groundwater for 26 December 2011, which were generated by integrating GRACE and other data within a numerical model of land surface water and energy processes, and (e) the official U.S. Drought Monitor map for 27 December 2011. There is generally good correspondence among the maps, with extreme drought around Texas and the southeastern U.S. and moderate to severe droughts on the west coast and to the west of the Great Lakes.

Scientific significance: GRACE is the first satellite mission able to observe changes in terrestrial water storage, including groundwater. These changes are based on GRACE measurements of Earth's time variable gravity field. Previous studies have confirmed GRACE's ability to observe terrestrial water storage changes and downscaled the coarse resolution GRACE fields through integration with other data in a numerical land surface model, a process known as data assimilation. The study described here is the first to take that work a step further and apply the GRACE data assimilation results to a specific water resources application, in this case drought quantification.

Relevance for future science and relationship to Decadal Survey: GRACE has survived well past its 5-year design lifetime, but it is showing signs of age. NASA has approved and is now developing a GRACE Follow-On mission, to be launched in 2017. The National Research Council's Decadal Survey in Earth Sciences also recommended a more advanced version of GRACE as a Tier 3 mission.

Software Tools for Data Manipulation, Visualization, and Analysis of Suomi-VIIRS Land and Cryosphere Products

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- VIIRS subsetting and reprojection tools developed by NASA's Land Product Evaluation and Testing Element (PEATE) have been released.
- Consistent cutouts of all VIIRS Land and Cryosphere EDRs are available for 1,000+ instrumented field validation sites.
- Both the operational (NOAA) and climate science (NASA) communities are using these data and customization tools for sensor cross-comparisons (e.g., VIIRS vs. MODIS/Aqua), algorithm comparisons, and temporal anomaly evaluations.

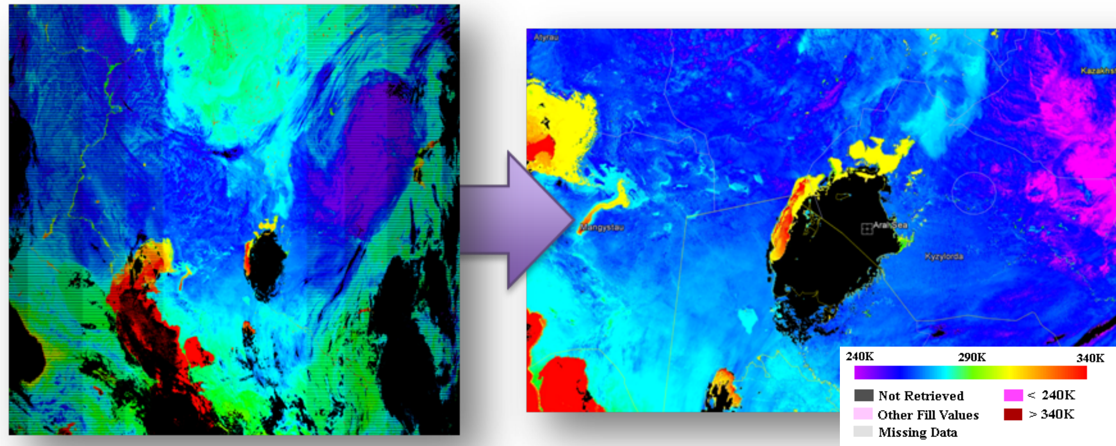

Figure 1: Land Surface Temperature EDR: Conversion from VIIRS Swath to Grid.

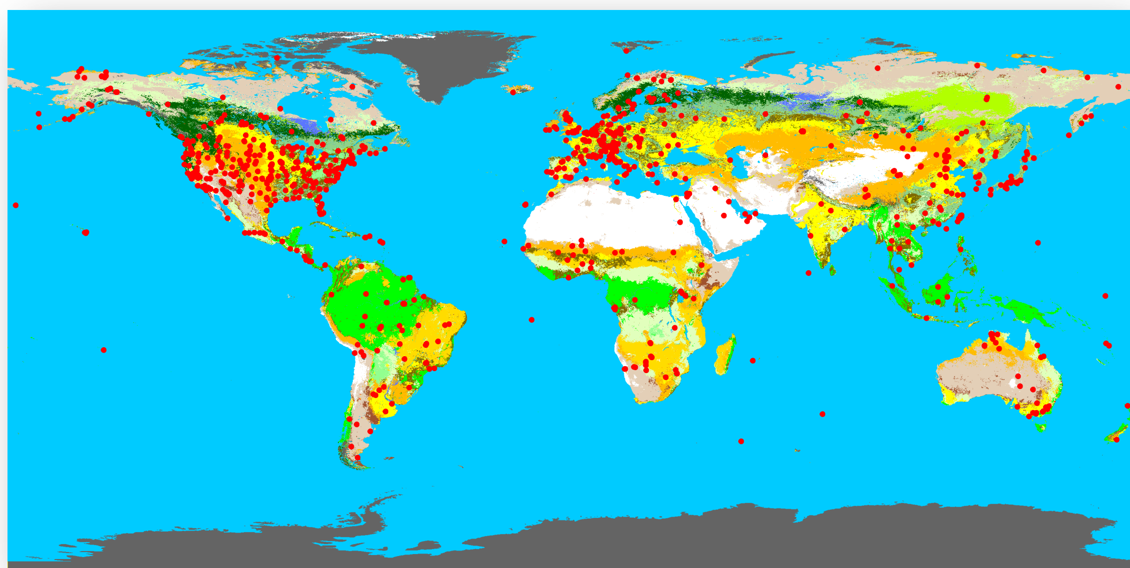

Figure 2: Suomi-NPP Land Validation Sites.

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Data Sources: Results of quality assessment of samples of VIIRS Land products made at the IDPS (Interface Data Processing System) and results of evaluation of improvements to the VIIRS Land Science algorithms derived by analyzing the products made at Land PEATE (Product Evaluation and Testing Element) using the new algorithms are placed on the web pages located at the Land PEATE website: **http://landweb.nascom.nasa.gov/NPP_QA/**

Technical Description of Images:

(**Figure 1**) Retrieval of VIIRS Land Surface Temperature (LST) EDR for March 3, 2012 (22:05 GMT) over the Aral Sea. A reprojection tool was developed to enable conversions of Suomi-VIIRS retrievals from satellite swath into common map projections (e.g., Geographic Lat/Lon and MODIS Sinusoidal) and data formats (e.g., GEOTIFF).

(**Figure 2**) Location of existing Suomi-NPP Land Validation Sites shown in red dots. VIIRS global land products are well stratified across Europe and North America, where there is an active presence of 'PI-maintained' and commissioned field stations (e.g., AERONET, FLUXNET, NEON, BSRN/SURFRAD, CEOS-LPV, and NOAA-CRN).

Scientific significance: A current focus of NASA's Earth System Science Program is to continue and enhance systematic observations from moderate resolution polar-orbiting sensors, and to generate and distribute validated, science-quality data product series. With the recent and anticipated changes to the land surface associated with the impacts of a warming world, increased global population pressure and rapid economic development, continuing these time-series through the next decades will be increasingly important. Building on NASA's investment in the Earth Observing System (EOS), the agency plans to continue the development of long term data records, and their supporting reference and validation datasets, through the Suomi-NPP and JPSS era. This will provide the underpinning long term measurements for the study of the land surface in the context of Climate and Global Change Research.

Relevance for future science and relationship to Decadal Survey: As NASA moves from a missions-focus to a focus on long term global measurements, the wealth of data available from in-situ observations (with different spatial and temporal supports) provides the foundation for understanding improvements to existing global land and cryosphere products, inter-comparing similar products from multiple sensors, and assessing the accuracy of products derived from new sensors or algorithms.